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Comparison of a leak behavior of an ID/ODSCC developed on SG tubes

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1. Introduction

Ni based alloy 600 materials have been used a lot for steam generator (SG) tubes which were being installed in Pressurized Water Reactor (PWR) nuclear power plants. Recently the trend is to replace alloy 600 SG tubes with alloy 690 materials because of its excellent corrosion resistance. The installed SG tubes in the existing PWRs have experienced various types of corrosion damage, such as a pitting, wastage and Stress Corrosion Cracking (SCC) on both the primary and secondary side. It is important to establish the repair criteria for the degraded tubes to assure a reactor integrity, and yet maintain the plugging ratio within the limits needed for an efficient operation. The primary coolant leakage to the secondary system is likely to suffer difficulties in the radiation safety management aspects when the steam generator tubes of the currently operating power plant have occurred SCC defects. Therefore, an evaluation of a coolant leakage behavior of the tubes containing stress corrosion cracks is very important under the pressure conditions of a operating or a virtual accident. The objectives of the present work are to develop the various forms of SCC tube defects and to evaluate a coolant leakage from SCC cracks of SG tubings at room temperature.

2. Methods and Results

2.1 Development of OD and IDSCC on SG tubes

High temperature thermally treated (HTMA) alloy 600 tubes were used for the purpose of the present work. The outside diameter (OD) and the wall thickness (WT) of the tubes were 19.05mm (0.75 in.) and 1.07mm (0.042 in.), respectively. Before an exposure to the tetrathionate solution, the specimens were heat treated at 600^{o}C for 36-48 hours to produce a microstructure that is susceptible to a cracking. The heat treatment was performed in a tube filled with an argon-nitrogen mixture gas to avoid an oxidation of the tube surfaces. The tubes were internally pressurized with nitrogen gas during an exposure. When a SCC grew through-wall, the internal gas pressure dropped, the SCC process was completed. Chemical compositions of the alloy 600HTMA tubes are shown in Table 1.

Table 1 Chemical compositions of the alloy 600MA tube (wt %)

Alloy	C	Si	Mn	P	Cr	Ni	Fe	Co	Ti	Cu	Al	B	S	N
600MA	0.025	0.05	0.22	0.07	15.67	75.21	8.24	0.005	0.39	0.011	0.15	0.001	0.001	0.01

2.2 Leak rate test

Leak rate tests were performed for the degraded tubes specimens at room-temperature using a high pressure leak-rupture test facility (Fig.1.). The facility consists of a water pressure pump, a specimen stage and manipulator, and a control system. It has similar features as described in NUREG/CR-6511 [2]. The inside of a tube was pressurized with water. The water pressure was increased until the tube showed a leakage. The first leak from the tube can be detected visually by the naked eye through a transparent plastic window. The leak rate at a given pressure was measured by weighing the water from the leak. The pressure was held at a certain value for a designated time to measure the leak rate. The measured data for the leak rate were recorded in a storage unit.

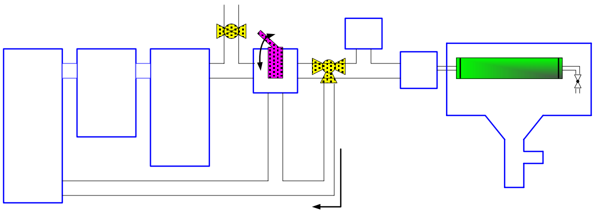

Fig.1. High pressure leak and burst test facility.

Several SG tube specimens with various SCCs were tested for the present investigation. The SCC flaws have a characteristically different flow path through a crack surface and a different leak behavior. Fig.2 shows the typical behavior of the pressure and leakage rate during water pressurization on a degraded SCC tube. In the case of that specimen, the main crack opened at 42MPa and a leakage began to be recorded. As the pressure increased, the crack opening area (COA) increased. Consequently, the leak rate also increased.

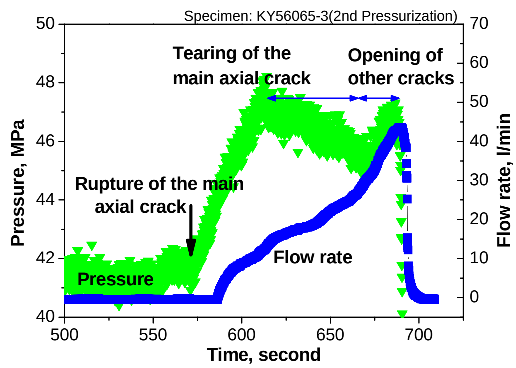

Fig.2. Typical leak behavior for a degraded SCC tube at room temperature.

The measured and compared leak rates of the ID and ODSCC with their length are shown in Fig.3. The longer the lengths of the defects, the greater the leakage but the leak rates do not necessarily corresponding to a usually estimated leak rate. In other words, despite the short length of the defect, the leak rate is larger than the longer one. This means that the SCC flaws have a characteristically different flow path through a crack surface. The leakage of the IDSCC is much larger than the ODSCC one. Because the length of inside is longer than outside (L1<L2) as shown in Fig.4.

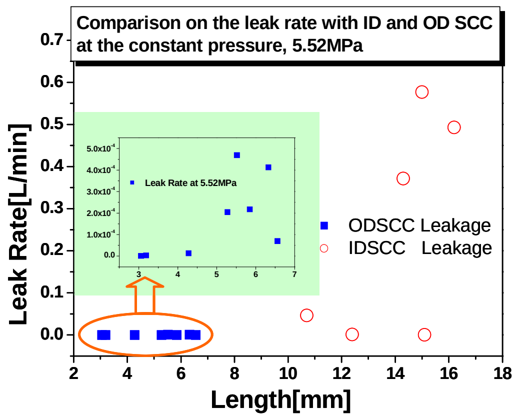

Fig.3. Comparison on the leak rate of the ID and ODSCC at a constant pressure.

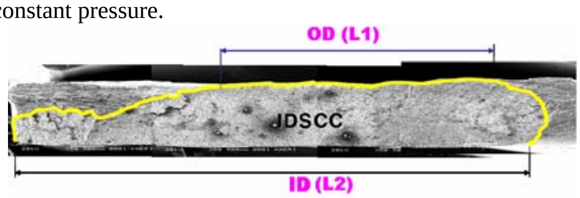

Fig.4. Feature of the cracks: the crack length of the inside is longer than the outside.

The leak rate of the tubes that have similar length of the inside or exterior tested depends on the internal water pressure as depicted in Fig.5.

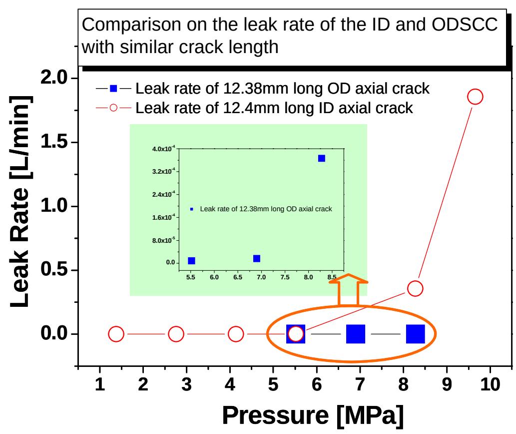

Fig.5. Comparison on the leak rate of the ID and ODSCC with a similar crack length.

While the leak rate of OD defect tube remains constant up to 8.5MPa, that of ID defect tube shows a lot increase of the leakage when the pressure reaches over 5.5MPa. This implies that ID side developed cracks are more easily opened than OD side initiated cracks.

3. Conclusions

- ◈ It is important to evaluate a coolant leakage behavior of tubes containing stress corrosion cracks.
- ◈ The SCC flaws have a characteristically different flow path through depending on the crack formation side(ID/OD).
- ◈ The leakage rate of an IDSCC crack was larger than that of the ODSCC one with the time or internal water pressure.

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